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COTTONS RESISTANT TO WILT AND ROOT KNOT AND THE EFFECT OF POTASH FERTILIZER IN EAST TEXAS

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In East Texas sandy-loam fields, Fusarium wilt, nematode root knot, and potash hunger frequently decrease cotton yields to a serious extent. Two or more of these troubles may be associated in the same field and these factors in combination present unusually difficult problems to the grower.

As a result of 6 years' tests in East Texas, the following cotton varieties (listed in decreasing order of probable value) were found to show high resistance to Fusarium wilt: Coker 4-in-1, Coker 100 Wilt Resistant Str. 39-5, Delta Dixie W. R. Str. 2, Tifton Dixie Triumph, Dixie Triumph 25-12, Dixie 14-5 Str. 2, Delfos 425, Miller 610, Deltapine 12, and Stonewilt. In addition, Coker 4-in-1, Coker 100 W. R. Str. 39-5, and three strains of Dixie varieties were found to be resistant to wilt and root knot together. The Miller 610 variety lost much of its wilt resistance when root-knot nematodes were abundant in the same field.

In these experiments, wilt resistance usually was lowered when the plants suffered from potash hunger ("rust"), and applications of 24 to 48 pounds of potash per acre increased the wilt resistance of most of the varieties tested. Potash also prevented symptoms of potash hunger, and greatly increased the yields. Phosphate had no apparent effect on wilt resistance of cotton.

The experiments indicate that by growing only the varieties of cotton that are resistant to the combination of wilt and root knot, by using high-potash balanced fertilizers, and by rotating cotton with Crotalaria and sorghum, farmers can prevent wilt and root knot from becoming a limiting factor in cotton production on their farms.

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COTTONS RESISTANT TO WILT AND ROOT KNOT AND THE EFFECT OF POTASH FERTILIZER IN EAST TEXAS

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Wilt, root knot, and potash hunger are closely associated troubles that seriously reduce the yield of cotton in East Texas each year. Many fields that are otherwise desirable are infested with disease-causing fungi and nematodes in such abundance that the land remains unprofitable and uncultivated much of the time. Fusarium wilt alone may kill as much as 50 percent of the plants in many East Texas cotton fields annually. Root knot decreases cotton yields usually without killing the plants and is especially destructive in sandy loam fields. Where cotton receives little or no potash fertilizer, potash hunger or "rust" dwarfs the plants and decreases the yields and wilt resistance in many of the sandy fields. On account of their importance, these three disorders of cotton were studied near Jacksonville from 1937 to 1942, and the results are given in this bulletin.

The setting of infested tomato or cabbage plants or fruit trees into disease-free fields often introduces root-knot nematodes and other disease-producing organisms. Fields may also become contaminated by infested seed, wind, and erosion water. The continued growing of cotton varieties that are susceptible to wilt, and the growing of many crops susceptible to root knot help to increase the causal organisms in the soil so that they greatly decrease the yields of certain crops, and consequently lessen the value of the land.

The literature on cotton wilt, root knot, and potash hunger is extensive, and the following information is summarized mainly from recent references in which many other articles are cited. The statement was made by Neal (10) that wilt is the most destructive disease of cotton in the United States. Young and Tharp (38) concluded that increased severity of potash hunger was associated with increased susceptibility to Fusarium wilt, and that there were large differences in percentages of wilt from year to year. Increases of nitrogen and phosphate fertilizer increased wilt, but increased potash fertilizer decreased wilt, according to Tharp and Wadleigh (27). However, Neal (13) concluded that increasing phosphate fertilizer did not increase wilt or the yield. Tables presented by Ware and Young (30) compare wilt resistance and agronomic quality of many varieties of cotton. Neal and Brown (12) determined that Delfos 425, Deltapine 12, and Miller 610 had strong resistance to wilt.

There is apparently only one physiologic race of *Fusarium vasinfectum* according to the data given by Tisdale and Dick (28). Similarly, Sherbakoff (16) and Cralley (3) determined that dissimilar varieties of cotton showed the same relative resistance to the respective isolates of the

wilt fungus, although there was much difference in the virulence of different isolates. Apparently one species of Fusarium caused the wilt of cotton, okra, Cassia, and tobacco in the tests by Armstrong, Hawkins, and Bennett (1).

Smith (17) gave a general report on the regional cotton variety wilt studies, of which the tests at Jacksonville, Texas, were a part. This article stated that wilt decreased the staple length and seed weight of the cotton, and that potash fertilizer decreased wilt. Preliminary reports on the regional cotton variety wilt studies were given by Young (32, 33, 34, 35). Smith (19) and Smith and Taylor (20) separated cotton varieties on the basis of their resistance to root knot and stated that resistance to root knot was found only in varieties that were developed in regions where the disease was severe. Smith (18) concluded that Coker 4-in-1 and Early Wilt varieties were resistant to both wilt and root knot, and that phosphate fertilizer had little effect on wilt percentages. Tisdale and Dick (28) classified cotton varieties on the basis of wilt susceptibility, and found that tolerant varieties may give the best yields where the wilt fungus is not very abundant.

Studies in Texas by Taubenhaus, Ezekiel, and Killough (21) showed that cotton wilt was most prevalent in fields with acid soils, while Taubenhaus and Christenson (24) secured evidence that several species of insects were natural carriers of the wilt fungus. Ezekiel and Dunlap (4) reported the distribution of cotton wilt in Texas in the 1939 season.

Concerning root knot, cotton is the sixth most susceptible kind of plant as listed by Watson and Goff (31), who regard root knot as the most destructive disease of crop plants in the old cultivated sandy fields of the South. Barker (2), King (7), and Tyler (29) reported that upland cotton *(Gossypium hirsutum L.)* generally tolerates root knot nematodes, but Sea Island and Egyptian cotton *(Gossypium barbadense L.)* are more susceptible. Sea Island 13B3 cotton had no wilt and only a minimum of root knot according to Miles (9) who compared the resistance of cotton varieties to wilt and root knot. Using three resistant and one susceptible variety of cotton, Neal (11) found that all four varieties developed abundant wilt when grown with *F. vasinfectum* and *H. marioni* together. Coker 4-in-1 and Cook 307 varieties survival combined wilt and root-knot attack longer than did the other varieties tested by Taylor, Barker, and Kime (25). Johnson (6) recommended Rhyne's Cook cotton for fields with both the wilt fungus and root-knot nematodes.

Rotation with Velvet beans, bare fallow, oats and bare fallow, and Crotalaria decreased tobacco root knot below 10 percent, according to Shaw (14). King and Hope (8) controlled root knot on cotton by summer fallowing with deep tillage for 3 years.

SYMPTOMS OF FUSARIUM WILT

Wilt is caused by a parasitic fungus named *Fusarium vasinfectum* Atk. It enters cotton roots from the soil and grows mainly in the water-

conducting vessels of the roots and stems, causing the plants to wilt and shed their leaves (Fig. 1). An early symptom of wilt consists of large yellow or brown areas near the margins of the leaves (Fig. 1). Stunting is another early symptom of wilt affecting some plants, with the stem nodes (joints) enlarged and the internodes abnormally short. Wilting plants more than three inches tall usually show some black or brown discoloration in the woody parts of the roots, leaf petioles, and lower parts of the stems (Fig. 2). Small plants commonly wilt and die quickly, but large plants with wilt may remain alive for many days. In severe cases, wilt may kill most of the plants in a field of susceptible cotton (Fig. 5).

Fig. 1. Early symptoms of Fusarium wilt in cotton. At left, a small stunted plant with wilted leaves growing beside a normal plant. At right, an affected leaf with withered tip. The dead part of the leaf is brown with a yellowish border.

Fusarium wilt was the only wilt disease involved in this work. Another kind of cotton wilt, caused by a different fungus (Verticillium), occurs locally in neutral or calcareous soils of Central and West Texas. Cotton varieties at Jacksonville were not tested for resistance to Verticillium. However, Ezekiel and Taubenhaus (5) reported that some cotton varieties resistant to Fusarium wilt are susceptible to Verticillium (Waxahachie) wilt. Taubenhaus, Ezekiel, and Rea (22) showed that central blackening of cotton stems was an important symptom of Verticillum wilt.

It is important to distinguish wilt from cotton root rot, caused by the fungus, *Phymatotrichum omnivorum* (Shear) Duggar. In the case of wilt, the bark remains normal on the large roots and on the base of the stem until the plant dies. In contrast, root rot soon kills the bark on the large roots and base of the stem and the brown fuzzy strands of the fungus often may be seen on the surface of the bark. The bark becomes gray and decayed, and soil often clings to the dead bark. A reddish-

Fig. 2. The most reliable symptom for identifying Fusarium wilt in cotton is the black or brown streaks in the woody part of the stem.

brown discoloration usually may be seen beneath the bark near the margin of infected tissue. Plants with root rot commonly die quickly and the leaves usually remain on the plants for many days. Fields often show large areas of plants killed by root rot, while plants with Fusarium wilt often occur scattered among healthy plants throughout the field. All known cotton varieties are susceptible to root rot.

SYMPTOMS OF POTASH HUNGER OR "RUST"

When cotton plants suffer from insufficient potassium (designated as potash in fertilizers) in the soil, the leaves usually develop distinct symptoms after the plants are several inches tall. Yellowish-white mottling appears, and large yellow spots or irregular areas develop between the veins. Many brown spots varying in size develop in the yellowed tissues between the veins and around the margins of the leaves. Breaking of the browned leaf margins gives the foliage a ragged appearance and the leaf margins sometimes curl downward. Black leaf spot caused by the fungus, *Macrosporium nigricantium* Atk., frequently develops in the yellowed areas of the leaves. Potash hunger causes the leaves to fall off early in the summer (Fig. 4). The plants usually are dwarfed and bear

small, defective bolls. Plants with serious potash deficiency commonly die in July and August, and the yield is seriously decreased.

SYMPTOMS OF ROOT KNOT

Root knot is caused by a parasitic species of nematode worm of microscopic size. These nematodes *(Heterodera marioni* (Cornu) Goodey) live in the soil and penetrate the roots of cotton and other plants. The feeding of the worms irritates the tissues, causing swellings 1/32 to 1/4 inch in diameter in the roots of upland cotton (Fig. 3). When the root knots become large or numerous on plants, they decrease the yield and may cause early death of the plants. The nematodes cause the tufted root symptom on some varieties of cotton (Fig. 3).

Fig. 3. Symptoms of nematode root knot on cotton. On left, the tufted-root symptom on Dixie Triumph 55-85 variety. On right, large root knots on a susceptible variety.

EXPERIMENTAL PROCEDURE

In these studies, the type of experiment varied somewhat from year to year and various tests were located in different fields. Furthermore, the diseases involved were different in the various experiments. For these reasons, the results of each experiment or group of similar experiments are given more or less separately and the particular conditions under which each experiment was carried out are discussed along with the results for that experiment.

Moderately susceptible varieties of cotton may appear to be resistant to mild attacks of disease-producing organisms. Hence, disease resistance

was determined accurately only under epidemic conditions when the causal agents were abundant. Fields containing abundant parasites were used in this work.

Control of wilt by potash fertilizers and resistant varieties

Fertilizers and wilt resistant varieties of cotton were studied in 1939 to 1941 in experiments which were a part of a series of studies conducted in several states in cooperation with the Division of Cotton and Other Fiber Crops and Diseases of the U. S. Department of Agriculture. Dr. H. D. Barker and Dr. A. L. Smith of that Division furnished the seed and outline for planting. The part of these studies carried out in Texas were made on the B. Pippin farm near Gallatin in Cherokee County. The results for East Texas are included in Tables 1, 2, 3, and 8. These fields were practically free from root-knot nematodes. Boll weevils were controlled by dusting the cotton plants with calcium arsenate.

Variety-fertilizer tests (1937-1939). These experiments were conducted on the Sawyer fine sandy loam soil in which the Fusarium wilt fungus was present and root-knot nematodes were practically absent. Single-row plots were used with rows 100 feet long and 42 inches apart. The varieties and fertilizers were randomized together and each combination was used in three replicates. Fertilizers were used at a rate of 400 pounds per acre in 1937 and 600 pounds per acre in 1938 and 1939. Half of the nitrogen fertilizer was applied as a side dressing early in June. Ceresan treated seed was planted by hand during the latter part of April each year. The plants were thinned to an average spacing of 5 inches in the row. Counts were made of the wilted and dead plants in May, June, July and August and the cotton was picked in August and September.

The following varieties of cotton showed adequate wilt resistance with large yields of good-staple cotton (Table 1): Clevewilt, Cook 144-68, Dixie Triumph 25-12, Dixie 14-5 Str. 2, Dixie Triumph 55-85, Miller 610, Rowden 2088, Coker 4-in-1, and Deltapine 12. Miller 610 showed the highest average yield. Cook 307, Toole, and Half and Half were short staple varieties. Sea Island cotton was immune to wilt but most of the bolls fell off in dry weather. The cotton rows without potash fertilizer (6-8-0) usually showed severe symptoms of potash deficiency while these symptoms of potash hunger were practically absent from the rows with 6-8-8 fertilizer, and were mild and uncommon in the rows with 6-8-4 fertilizer (Fig. 4).

The following nine varieties in Table 1 were used in calculating the effects of potash fertilizers: Clevewilt 6, Cook 144-68, Cook 307, Dixie Triumph 25-12, Dixie 14-5-2, Dixie Triumph 55-85, Miller 610, Coker 100, and Half and Half. The use of fertilizers containing 4 percent potash resulted in increases of 18 to 53 (Av. 28.5) percent in the average yield of the nine main varieties as compared with a 6-8-0 fertilizer. Increasing the potash to 8 percent gave additional increases of 3 to 24 (Av. 10.5) percent in the 3-year average yields. The average yield of all nine varieties for three years was 677 lb. of seed cotton per acre

Table 1. Varietal wilt resistance of cotton and the effects of potash fertilizers, 1937-1939.

Variety	Fertilizer	Data on wilt and yield—average of 3 rows								Percent yield increase over	
		1937		1938		1939		Average			
		Plants wilted, %	Seed cotton, lbs. per Acre	Plants wilted, %	Seed cotton, lbs. per Acre	Plants wilted, %	Seed cotton, lbs. per Acre	Plants wilted, %	Seed cotton, lbs. per Acre	6-8-0	Half and Half
Half and Half	6-8-0	9.3	468	37.1	485	31.8	492	26.1	482	0	0
"	6-8-4	7.7	542	36.9	742	19.3	769	21.3	684	42	0
"	6-8-8	2.4	570	18.4	842	12.9	782	11.2	731	52	0
Clevewilt 6 and 7	6-8-0	0.8	566	0.3	632	0.7	857	0.6	685	0	42
"	6-8-4	0.8	674	0.4	980	0.4	1023	0.5	861	26	26
"	6-8-8	0.3	714	1.3	1008	1.7	1015	1.1	912	33	25
Coker 4-in-1	6-8-0	----	----	----	----	1.8	786	----	----	0	60
"	6-8-4	----	----	----	----	1.1	926	----	----	18	20
"	6-8-8	----	----	----	----	1.0	951	----	----	21	22
Coker 100	6-8-0	5.6	528	36.4	421	9.0	655	17.0	535	0	11
"	6-8-4	2.5	559	21.1	831	8.8	777	10.8	722	35	6
"	6-8-8	3.1	658	14.2	1072	5.7	771	7.7	834	56	14
Cook 144-68	6-8-0	0.8	569	0.4	530	1.2	758	0.8	619	0	28
"	6-8-4	0.4	604	1.7	961	0.9	896	1.0	816	32	19
"	6-8-8	0.3	725	0.3	1094	1.0	991	0.5	937	51	28
Cook 307 (Rhyne)	6-8-0	0.7	629	1.1	667	1.7	763	1.2	686	0	42
"	6-8-4	0.9	747	0.3	994	1.3	922	0.8	888	29	30
"	6-8-8	0.1	696	0.1	1017	0 7	916	0.3	876	28	20
Deltapine 11A (D&PL)	6-8-0	----	----	11.9	458	----	----	----	----	0	—6*
"	6-8-4	----	----	4.7	896	----	----	----	----	96	21
"	6-8-8	----	----	5.3	942	----	----	----	----	106	12
Deltapine 12	6-8-0	----	----	----	----	1.2	662	----	----	0	35
"	6-8-4	----	----	----	----	1.6	818	----	----	24	6
"	6-8-8	----	----	----	----	2.1	978	----	----	48	25

*Minus sign means yield less than Half and Half variety.

Table 1. Varietal wilt resistance of cotton and the effects of potash fertilizers, 1937-1939. —Continued.

Variety	Fertilizer	Data on wilt and yield—average of 3 rows								Percent yield increase over	
		1937		1938		1939		Average			
		Plants wilted, %	Seed cotton, lbs. per Acre	Plants wilted, %	Seed cotton, lbs. per Acre	Plants wilted, %	Seed cotton, lbs. per Acre	Plants wilted, %	Seed cotton, lbs. per Acre	6-8-0	Half and Half
Dixie Triumph 25-12	6-8-0	2.3	611	0.3	693	1.4	817	1.3	707	0	47
"	6-8-4	1.3	707	0.1	972	0.8	804	0.7	848	20	24
"	6-8-8	1.6	591	0.1	1196	0.7	1010	0.8	932	32	27
Dixie 14-5, Str. 2	6-8-0	2.4	651	3.0	548	2 5	804	2.6	668	0	39
"	6-8-4	0.5	627	1.4	935	1.8	936	1.2	833	25	22
"	6-8-8	2.0	724	1.3	1089	1.9	962	1.7	922	38	26
Dixie Triumph 55-85	6-8-0	2.1	603	2.1	659	1.1	754	1 8	672	0	39
"	6-8-4	2.0	736	0.4	834	1.4	966	1.3	845	26	24
"	6-8-8	0.4	668	0.4	940	1.0	1077	0.6	895	35	22
Miller 610	6-8-0	1.2	513	4.8	692	3 3	805	3.1	670	0	39
"	6-8-4	0.9	757	2.2	1023	1.8	1004	1.6	928	39	36
"	6-8-8	1.7	746	0.8	1108	1.7	1012	1.4	955	43	31
Rowden 208S	6-8-0	----	----	3.4	450	1.4	791	2.4	621	0	27
"	6-8-4	----	----	1.4	978	1.7	926	1.6	952	53	25
"	6-8-8	----	----	1.0	1135	1.0	961	1.0	1048	69	29
Sikes Wilt Resistant	6-8-0	3.3	542	----	----	----	----	----	----	0	16
"	6-8-4	3.3	582	----	----	----	----	----	----	7	7
"	6-8-8	0.5	609	----	----	----	----	----	----	12	7
Sea Island 13B3	6-8-0	0	87	----	----	----	----	----	----	0	—81*
"	6-8-4	0	126	----	----	----	----	----	----	45	—77*
"	6-8-8	0	100	----	----	----	----	----	----	15	—82*
Toole (Perry)	6-8-0	1.1	669	1.0	681	----	----	1 1	650	0	36
"	6-8-4	0.5	690	0.6	936	----	----	0.6	813	25	27
"	6-8-8	0.3	765	0.3	1066	----	----	0.3	916	41	30

*Minus sign means yield less than Half and Half variety.

Fig. 4. Control of potash hunger.
A. Row in left center was Dixie 14-5-2 cotton with 6-8-8 fertilizer. Note freedom from potash hunger as compared with the severe symptoms in the next row (right center) of Cook 144-68 variety with 6-8-0 fertilizer. Only 3 plants had Fusarium wilt in these two rows.

B. The two center rows were Half and Half (left) and Coker 100 (right), both rows with 6-8-0 fertilizer, and both show severe symptoms of wilt and potash hunger. Beside these, on the left is a row of Toole cotton and on the right Miller 610 variety, both of which showed but little wilt and no potash hunger with the 6-8-4 fertilizer.

with 6-8-0 fertilizer, 870 lb. per acre with 6-8-4 fertilizer, and 948 lb. per acre with 6-8-8 fertilizer. In Table 1, percentages of wilted plants are shown in association with different percentages of potash fertilizer and cotton varieties differing in resistance to wilt. By a special method of calculation (38), for showing the proportion of wilt that was associated with each grade of potash fertilizer, the above mentioned nine varieties showed the following proportions:

45.7	Percent	of	the	wilt	was	associated	with	6-8-0	fertilizer,
33.3	"	"	"	"	"	"	"	6-8-4	"
21.3	"	"	"	"	"	"	"	6-8-8	"

Thus, the 4 percent potash in the fertilizer decreased the wilt 12.7 percent, and 8 percent potash decreased the wilt an additional 11.7 percent. The potash fertilizer decreased the percentages of wilted plants in 24 of the 27 tests and in 8 of the 9 varieties. Clevewilt showed the strongest wilt resistance and this was the only variety that did not show a response to the potash fertilizers.

Studies in 1941. Wilt resistant varieties were planted on land which had been fertilized with 6-8-8 fertilizer at the rate of 500 pounds per acre. Each of the six varieties were replicated eight times. The plants suffered from drought and aphid injury during the summer. As may be seen in Table 4, Coker 100 W. R. Str. 39-5, Coker 4-in-1, Miller 610, and Tifton Dixie Triumph all showed strong wilt resistance and produced large yields of good staple cotton. The 6-8-8 fertilizer apparently minimized the percentage of wilt as compared with previous seasons.

Testing Phosphate Fertilizer in Relation to Wilt (1940)

Applications of phosphate fertilizer were accompanied by increases in cotton wilt in some soils according to Tharp and Wadleigh (27). In 1940, the effect of fertilizer with 6 percent phosphate was compared with fertilizer with 12 percent phosphate. Fertilizers at the rate of 600 pounds per acre were applied in the row on April 18 and the seed was planted on April 22. The plants received abundant, well-distributed rains throughout the summer (except for a short drought in July).

Examination of the data in Table 2 shows no important differences in the percentages of wilt between the 6-6-6 and the 6-12-6 fertilizer. However, this field had received much phosphate-containing fertilizers during previous seasons, and probably had abundant phosphate in the soil.

Effects of Phosphate and Potash Fertilizers on Yields (1941)

In this test, conducted in the other half of the field concerned in Table 4, each combination of varieties and fertilizers was arranged in duplicate with the fertilizers applied at the rate of 500 pounds per acre. The yields of the four vareities were combined in summarizing the yield on a fertilizer basis (Table 3) Potash hunger symptoms were serious in the rows with 6-8-0 fertilizer and in the rows without fertilizer. Even without potash, the cotton yielded more with 6-8-0 fertilizer than it did without any fertilizer. Because the soil was deficient in potash the yield was further improved by 6-8-20 fertilizer.

In contrast with Table 2, the data in Table 3 show no evidence that cotton yields were decreased by phosphate fertilizer, especially as summarized for all four varieties. A leaf test (by Dr. N. D. Morgan of the American Potash Institute) using leaves of cotton from rows to which no phosphate was added this year, revealed adequate phosphorus in the leaves. Apparently this soil had adequate phosphate fertilizer. The large yield of cotton resulting from the use of 10-0-10 fertilizer indicated that the cotton did not need the phosphate added with the 6-6-6 and 6-12-6 fertilizers.

This land was planted in tomatoes in 1940 which apparently decreased the infestation by the wilt fungus below its degree of abundance in the adjacent land with continuous crops of cotton for six years. Thus, Half and Half cotton showed more wilt in Table 4 with 6-8-8 fertilizer than it did in Table 3 with 6-8-0 and 0-0-0 fertilizer applications in these two parts of the same field and the same year. Accordingly, a rotation of only one year seemed beneficial in decreasing the infestation of the soil with the wilt fungus. Wilt had little effect on the yields of the four varieties included in Table 3.

Wilt Resistance Studies at College Station (1942)

Five varieties of cotton (Coker 100, Deltapine 14, Rogers Acala 111, Stoneville 2B and Coker 4-in-1) were planted in Lufkin sandy loam soil

Table 2. Effects of wilt and phosphate fertilizers on the yield of cotton varieties—1940.

Variety	Fertilizer	Plants wilted* %	Seed cotton, lbs. per Acre	Yield increase over Half and Half %
Half and Half	6-6-6	41.4	1147	0
"	6-12-6	37.0	1084	0
Coker 4-in-1	6-6-6	4.1	1850	61
"	6-12-6	8.4	1762	63
Delfos 425	6-6-6	3.4	1801	57
"	6-12-6	1.5	1693	56
Dixie Triumph 06-366	6-6-6	2.6	1925	68
"	6-12-6	2.0	1870	73
Early Wilt (Wann.)	6-6-6	2.3	1857	62
"	6-12-6	2.1	1800	66
Miller 610	6-6-6	4.0	2090	82
"	6-12-6	4.1	1964	81

*Exclusive of dead plants many of which presumably were killed by wilt; calculation based on 200 plants per row.

Table 3. Varietal resistance to wilt and effects of different fertilizers on cotton—1941.

Variety	Fertilizer	Plants wilted %	Seed cotton, lbs. per Acre	Yield increase over Half and Half %
Half and Half	0-0-0	5.3	578	0
"	6-8-0	8.0	801	0
"	6-8-20	4.7	1036	0
"	6-6-6	7.3	1171	0
"	6-12-6	8.7	1048	0
"	10-0-10	6.0	1207	0
Miller 610	0-0-0	0.0	828	43
"	6-8-0	0.7	1004	25
"	6-8-20	0.7	1501	45
"	6-6-6	0.7	1349	15
"	6-12-6	1.6	1385	32
"	10-0-10	1.0	1362	13
Stonewilt (Wannamaker)	0-0-0	0.0	801	39
"	6-8-0	0.3	1024	28
"	6-8-20	0.0	1322	28
"	6-6-6	0.3	1238	6
"	6-12-6	0.7	1324	26
"	10-0-10	0.3	1230	2
Tifton Dixie Triumph	0-0-0	0.0	762	32
"	6-8-0	0.3	1029	28
"	6-8-20	0.0	1297	25
"	6-6-6	0.3	1280	9
"	6-12-6	0.3	1362	30
"	10-0-10	0.0	1429	18
(Average of 4 varieties)	0-0-0	1.3	742	----
"	6-8-0	2.3	965	----
"	6-8-20	1.4	1290	----
"	6-6-6	2.2	1260	----
"	6-12-6	2.8	1280	----
"	10-0-10	1.8	1307	----

Table 4. Wilt resistance of cotton varieties and yields—1941.

Variety	Plants wilted %	Seed cotton, lbs. per Acre	Yield increase over Half and Half %
Half and Half	11.3	966	0
Coker 4-in-1, Str. 4	3.1	1135	19
Coker 100 W. R. Str. 39-5	1.2	1185	24
Miller 610	1.3	1159	21
Stonewilt (Wannamaker)	0.4	1061	11
Tifton Dixie Triumph	1.1	1105	16

in the Field Plot of the Division of Plant Pathology and Physiology at College Station in 1942. The seed was planted on April 14, and 200 to 300 pounds of 6-12-6 fertilizer per acre was distributed in the row with the seed. Each variety was replicated 16 to 22 times in single-row plots 25 feet long. The cotton was picked from September 22 to 25. As wilt killed a large percentage of the plants of the susceptible varieties, the experiment showed the value of the resistant Coker 4-in-1 cotton in this region (Table 5, Figs. 2, 5). After harvest, data on wilt infection were obtained by cutting the stems and noting the presence of wilt symptoms. (Data furnished by Dr. A. A. Dunlap).

Table 5. Effects of wilt on cotton varieties at College Station—1942.

Variety	Plants with wilt %	Yield of seed cotton, lbs. per Acre
Coker 100-5	93	648
Deltapine 14	92	828
Rogers Acala 111	76	1019
Stoneville 2B	93	1062
Coker 4-in-1, Str. 4	34	1443

Resistance of Cotton Varieties to Root Knot (1939-1941)

These experiments were conducted at the Jacksonville Laboratory on Norfolk fine sandy loam soil abundantly infested with the root-knot nematode but in which the wilt fungus was absent. The soil had received liberal applications of a complete fertilizer. Three to five replications of the varieties were planted late in April in randomized plots. The plants were plowed out and the roots were classified for root knot in September and October. Based on root-knot susceptibility, the plants were placed in three classes: (1) plants without root knot, (2) plants with only one or a few small knots, and (3) plants with large or numerous knots.

The following varieties showed all plants with severe root knot: Clevewilt 7, Coker 100, Cook 144-68, Delfos 425, Deltapine 12, Deltapine 44-51.

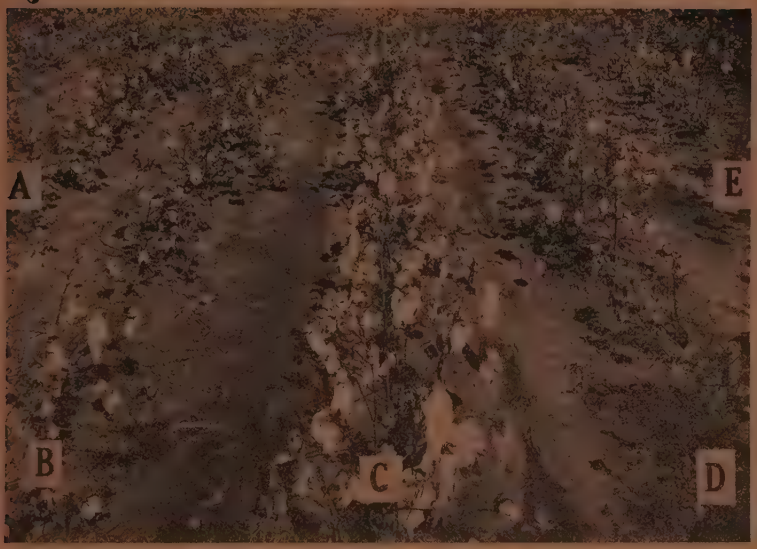

Fig. 5. Potograph taken in a field infested with the wilt fungus at College Station showing the following varieties: Row A, Coker 100-5; B, Rogers Acala 111; D, Rogers Acala 111; E, Deltapine 14 all seriously affected with wilt. In row C the superior stand and yield of the Coker 4-in-1 cotton was due to its wilt resistance.

Deltapine 11A (D&PL), Dixie 14-5-2, Dixie Triumph 25-12, Dixie Triumph 55-85, Half and Half, Lankart, Lone Star, Mebane, Miller 610, Qualla, Rogers Acala 111, Rowden, Stoneville 2B, and Texacala. Coker 4-in-1, Rhyne's Cook, and Hi-Bred showed some resistance to root knot. All varieties tested showed serious amounts of root knot although some varieties showed fewer and smaller knots than others. Because of variations in nematode populations, varietal resistance was judged mainly on the largest percentages of severe root knot in any field in any year. Thus, one test in an area with heavy infestation of nematodes gave more information about resistance than was learned from several tests over a 3-year period in areas with light infestations.

Evidence of host specialization. These studies were conducted in a field used for soil fumigation tests from 1936 to 1939. Wooden borders were built on the experimental plots 2½ x 20 ft. Fourteen of these enclosed plots were checks with untreated soil in which 40 to 100 percent of the watermelon test plants had severe root knot in 1939. However, only 0 to 4 percent of the cotton plants (15 varieties) showed severe root knot in these same plots in 1940. This indicated that the nematodes which had been living on the watermelons for three years did not severely attack cotton the following year. Sherbakoff (15) found evidence of

similar host specialization of the root-knot nematode. However, a plot in which tomatoes had severe root knot in 1936 to 1939 also showed severe root knot on several varieties of cotton in 1940 and 1941.

Combined Varietal Resistance to Wilt and Root Knot (1941-1942)

The resistance of cotton varieties to heavy infestations of both the wilt fungus and root-knot nematodes was studied on the Ault farm near Crafts in Cherokee County, in cooperation with Superintendent P. R. Johnson of Substation No. 2, Tyler, and Dr. N. D. Morgan of the American Potash Institute. Two-thirds of this field is Ruston loamy fine sand, and the remainder is Bowie fine sand. The field was planted in cotton in 1936, and in alternate crops of corn and cotton thereafter. Wilt was general in the field in 1940. In 1941, the central portion of the field was planted to Bryant Mebane cotton and the guard rows (2 and 101-106) were planted with other varieties as shown in Table 6 (Fig. 6).

Table 6. Effect of root knot on wilt resistance of cotton varieties. Ault farm—1941.

Variety	Row number	Number of plants	Fertilizer	Plants wilted on August 5 %
Half and Half	103	261	0-0-0	34.3
Coker 4-in-1, Str. 4	101	337	6-8-8	0.3
Coker 100 W. R.	2	320	6-8-20	0
Mebane (Bryant)	3	176	0-0-0	30.7*
Mebane (Bryant)	98	209	6-8-8	72.2*
Miller 610	102	341	6-8-20	29.0†
Tifton Dixie Triumph‡	104	249	6-6-6	2.0
Cook 307 (Rhyne's Cook)	105	73	0-0-0	0
Stonewilt (Wannamaker)	106	220	6-6-6	45.0†

*Most of the Mebane cotton plants died of wilt and disappeared before and after August 5.
†Wilt resistance was greatly decreased by root knot.
‡This variety probably is the same as Dixie Triumph Wilt Resistant Str. 21, used in 1942.

Coker 4-in-1 and Cook 307 (Rhyne's Cook) cotton showed strong resistance to the combined wilt and root-knot disease. Similarly, Coker 100 Wilt Resistant Str. 39-5 and Tifton Dixie Triumph were practically uninjured by wilt. In contrast, nearly 90 percent of the Mebane cotton was killed by wilt in the center of this field. Miller 610 and Stonewilt cotton lost much of their wilt resistance due to nematode infection in this field. Young (37) previously stated that root knot increased the severity of wilt.

Cotton varieties were tested (Table 7) in the same field on the Ault farm in 1942 to add to the information obtained in 1941. The 66 rows were 200 feet long and 48 inches apart. On April 18, 333 pounds per acre of 6-8-8 fertilizer was placed in each row. Ten varieties of cotton were randomized and replicated six times, and two other varieties (Harper U Mebane and Rhyne's Cook) were planted in triplicate guard rows. The seed was planted on April 27 and a thick stand of seedlings emerged which were thinned to 500 plants per row on May 15.

Fig. 6. Above: Bryant Mebane cotton (center row) dwarfed or killed by Fusarium wilt, in contrast to Dixie Triumph Wilt Resistant Str. 21 on left, and Delta-Dixie Wilt Resistant Str. 2 on right (1942).

Below: Same field in 1941 with Mebane cotton (on left) ruined by wilt and wilt-resistant Coker 4-in-1 variety on right without visible injury. This field was infested with root-knot nematodes in addition to the Fusarium wilt fungus. An application of 400 lb. per A. of 6-8-8 fertilizer prevented potash deficiency symptoms in this field.

Table 7. Resistance of cotton varieties to the combined wilt and root-knot diseases. Ault farm—1942.

Variety	Plants killed or wilted, %	Data taken on September 25 to 30						Weighted symbol of root-knot resistance	Yield of seed cotton	
		Total No. of plants	Percentage of plants						Lbs. per Acre	Increase over Half and Half %
			Dead	Living plants in root-knot classes						
				0	1	2	3	4		
Half and Half	25.1	1939	21.2	0.5	6.7	9.7	27.9	55.2	169	499	0
Coker 4-in-1, Str. 4	8.8	2356	3.9	24.8	41.0	13.9	12.4	7.9	376	744	49
Coker W. R. 39-5	10.8	2459	16.6	0.4	5.9	8.7	23.9	61.1	161	676	35
Cook (Rhyne)*	4.9	1290	3.5	2.7	23.5	19.1	27.1	27.6	247	739	48
Deltapine 14 (44-51)	27.3	1999	59 0	0.7	6.3	11.2	22.0	59.8	166	332	—33†
Delta-Dixie W. R. 2	8.9	2419	13.5	2.3	7.7	12.6	29.4	48.0	187	720	44
Dixie Triumph W. R. 21	5.6	2445	5.6	1.0	4.0	7.0	18.3	69.7	148	642	29
Wonder Dixie Tr. W. R. 9	15.3	2052	18.3	0.2	3.8	9.0	24.0	63.0	154	579	16
Mebane (Bryant)	40.3	1491	36.4	1.0	4.0	9.3	20.1	65.6	155	353	—29†
Mebane (Harper U)*	43.9	[illegible]	40.0	0.0	3.8	4.8	26.9	64.5	148	424	—15†
Miller 610	16.8	2128	37.2	0.2	3.7	7.4	19.8	68.9	147	451	—10†
Stoneville 2B	23.3	2139	32.4	1.0	8.5	16.0	27.5	47.0	189	548	10

*In 3 guard rows; the other 10 varieties were randomized in 6 rows apiece; all rows were thinned to 500 plants per row on May 15.
†Minus sign means yield less than Half and Half variety.

The wilted plants were counted at five different times in June and July, and these were removed from the field in June, but not in July. Due probably to the removal of wilted plants and the hot, dry weather from June 25 to August 15, there was little spread of wilt after July 15. The cotton was picked four times from August 13 to September 24. After harvest, all of the cotton plants were loosened with a sweep blade and pulled, and the roots were classified for abundance of root knots, using a system (19) based on the percentage of lateral roots with root knot per plant. The plants in each row were divided into six classes as follows:

Class 0 Plants without root knots.
1 Plants with knots (usually 1 to 10 apiece) on only 1 to 25 percent of the lateral roots or with knots on the tap root only.
2 Plants with 26 to 50 percent of the roots knotted.
3 Plants with 51 to 75 percent of the roots knotted.
4 Plants with 76 to 100 percent of the roots knotted.
5 Dead plants with decayed roots.

The degrees of varietal resistance to root knot are shown by the percentages of plants in the different classes (Table 7). The following method was used to combine these class percentages into a weighted symbol of root-knot resistance for each variety to give a simple numerical expression in each case. The percentage of plants in Class O was multiplied by 5; in Class 1, by 4; in Class 2, by 3; in Class 3, by 2; and the percentage in Class 4 was multiplied by 1. These product percentages were added to give the weighted symbol of resistance for the variety. Using Bryant Mebane for example in Table 7 the formula is used as follows:

1.0		4.0		9.3		20.1		65.6	
x5		x4		x3		x2		x1	
5.0	+	16.0	+	27.9	+	40.2	+	65.6	= 154.7 *(155)*

The value 155 is the weighted symbol that is useful in expressing root-knot resistance in one figure.

A sufficient number of plants (820 to 1438) of each variety remained alive to provide an adequate basis for showing any resistance to root knot. It may be assumed that large percentages of the roots of the other plants bore knots before the plants died. Some of the cotton seedlings showed nematode infection when they were thinned in May.

Root knot probably did not decrease cotton yields seriously on the plants in Class 1. However, there usually were 50 to 100 or more knots on the roots of each plant in Classes 3 and 4, and such plants were evidently damaged by the disease. The effects of wilt and root knot were inseparably associated in decreasing the cotton yields in this field.

Miller 610 and other very susceptible varieties showed large root knots and some of the susceptible varieties including Miller 610, Coker 100 W. R., and Dixie Triumph W. R. Str. 21 showed a large percentage of the plants with the tufted root symptom of root knot (Fig. 3). However, the tufted-root symptom was rare on the susceptible Mebane and Delta-

pine 14 varieties. Some of the Wonder Dixie Triumph and Rhyne's Cook plants showed enlarged roots with irregular swellings probably due to nematode infection.

Coker 4-in-1 variety was outstanding in its resistance to root knot because most of its roots were classified in the first three groups. Rhyne's Cook was the only other variety that showed prominent resistance to this disease. All of the other 10 varieties were very susceptible to root knot (Table 7). Coker 100 W. R. Str. 39-5 and the three Dixie varieties were very susceptible to root knot, but this disease did not greatly decrease their wilt resistance. These four varieties, although showing a high percentage of knotted roots, were very tolerant to root knot.

Root-knot nematodes had the general effect of decreasing the wilt resistance of cotton varieties probably by wounding the roots and by decreasing the vigor of cotton plants. This effect was very prominent in the Miller 610 variety in which root knot greatly decreased the wilt resistance (Tables 1, 6, 7). In contrast, root knot showed only a moderate effect in decreasing the wilt resistance of Coker 100 W. R. Str. 39-5 and the three Dixie varieties, probably because these varieties are tolerant to root knot as indicated by their satisfactory yields (Table 7). Despite the extremely large amount of root knot, plants of Dixie Triumph W. R. Str. 21 retained their leaves unusually well during the drought and were apparently drought resistant. Apparently due to their resistance to both wilt and root knot separately and in combination, Coker 4-in-1 and Rhyne's Cook showed little decrease in wilt resistance through nematode infection. Wilt resistance was so low in Mebane, Deltapine 14, Half and Half, and Stoneville 2B varieties that root knot caused no further apparent decrease in their wilt resistance. Stoneville 2B merited favorable mention because of its fair yield under these severe conditions.

Staple Lengths and Lint Percentages

The staple length and lint percentage of many of the varieties used in these studies are given in Table 8. This table was summarized mostly from data supplied by Dr. H. D. Barker from eleven-boll samples taken from each row every year from the fields mentioned in Tables 1 and 2. The staple lengths, originally calculated by Dr. Barker to hundredths of a thirty-second part of an inch, were changed to inches and fractions thereof for this table.

Discussion of Wilt Resistance

The wilt fungus, *Fusarium vasinfectum*, is a facultative parasite that is naturally most destructive in weak plants. Accordingly, plants that are weakened by potash hunger or by root knot are usually more susceptible to wilt than plants having adequate fertilizer, normal roots, and good growing conditions. Although tests of many varieties may show intergradations it is helpful to arrange the cotton varieties in four groups

based on their resistance to the combination of wilt and root knot: (1) Mebane and Half and Half cotton are very susceptible to both wilt and root knot, and root knot had little effect in decreasing their low wilt resistance. (2) Three of the Dixie varieties were resistant to wilt and tolerant to root knot, and root knot did not greatly decrease their wilt resistance. (3) Miller 610 and Stonewilt were resistant to wilt but susceptible to root knot, and root knot greatly decreased the wilt resistance of these varieties. (4) Coker 4-in-1 and Rhyne's Cook were resistant to wilt and root knot separately and together, and root knot had little effect in decreasing their wilt resistance.

Table 8. Staple length and percentage of lint of cotton varieties.

Variety	Years in test	Average staple length, inches	Average percentage of lint
Clevewilt 6	2	1	36.6
Clevewilt 7	1	1	34.1
Coker 4-in-1	3	1 2/32	36.6
Coker 100 W. R. Str. 39-5	1	1 1/32	37.5
Coker 100	3	1 1/32	36.3
Cook 144-68	3	31/32	36.6
Cook 307 (Rhyne's Cook)	3	27/32	37.6
Delfos 425	1	1 3/32	34.4
Deltapine 11A (D&PL)	1	1	41.6
Deltapine 12	1	1	38.0
Deltapine 14*	2	1	39.0
Dixie 14-5 Str. 2	3	1	33.7
Dixie Triumph 06-386	1	30/32	37.5
Dixie Triumph 35-12	3	1 1/32	38.6
Dixie Triumph 55-85	3	29/32	34.1
Early W. R. (Wann.)	1	30/32	39.6
Half and Half	5	25/32	45.1
Hi-Bred*	2	28/32	42.0
Miller 610	5	31/32	38.2
Rogers Acala 111*	2	1 1/32	36.0
Rowden 2088	2	30/32	34.6
Sikes	1	1	33.0
Stoneville 2B*	2	1 1/32	34.0
Stonewilt	1	1 2/32	35.9
Tifton Dixie Triumph	1	1 1/32	37.1
Toole	2	28/32	36.2

*Data by Division of Agronomy, based on experiments at Substation 11, Nacogdoches, and Substation 2, Tyler.

METHODS OF DISEASE CONTROL

Based on local experience and the recorded work of others, the following methods are recommended for controlling wilt, root knot, and potash hunger under East Texas conditions. Special care should be taken to control these diseases in sandy loam soils because they are more destructive in such soils than in clay soils. Crop rotations should be planned (36) so that only immune or resistant crops are planted in soil that is badly infested with the disease-causing organisms. Root knot can be controlled in one year by planting disease-immune crops in rows, hand weeding and hoeing the seedlings, and cultivating the crop every 10 to 14 days throughout the growing season. If weeds are allowed to grow, how-

ever, it may require several years to accomplish the same purpose even if immune crops are planted.

Crotalaria spectabilis, sorghum, and Velvet bean are practically immune to root knot and are recommended for starving the nematodes out of the soil. Although not a forage crop, crotalaria produces a large yield of nitrogenous organic matter for plowing into the soil. It should be planted in March, and the green plants should be disked and plowed into the soil in the fall. Sorghum has the advantage of producing a forage crop in addition to starving the nematodes, but commonly adds little humus to the soil. Texas Agr. Exp. Sta. Progress Rept. 837 by G. H. Godfrey showed that root knot was profitably controlled by plowing land 3 times to dry the nematodes in hot weather.

Certain nematode-resistant crops grow well and produce good yields in infested soil. Such resistant crops adapted for use in East Texas are corn, Bermuda grass, oats, Iron and Brabham cowpeas, Porto Rico sweet potatoes, peanuts, and Laredo soybeans. Moderately resistant crops may maintain nematodes in the soil so that following susceptible crops may be seriously affected by root knot. Cultivating land often enough to keep it free from green plants, and keeping the soil crust broken will starve out the nematodes completely or nearly so within a year, but this method is expensive and leaves the loose soil exposed to erosion and loss of organic matter. Hence, growing an immune crop on the land for a few years, keeping it practically free from weeds, and plowing the refuse plant material into the soil is the preferable method of controlling the nematodes. Such a procedure enriches the soil at the same time.

With cotton, the use of 300 to 400 pounds of 6-8-8 or 4-10-7 fertilizer per acre provides adequate potash to prevent serious potash hunger (deficiency) symptoms.

In the case of cotton, it is best to avoid land that is badly infested with disease-causing parasites. For land with slight or no infestation by these soil parasites, tests in East Texas by the Texas Agricultural Experiment Station have resulted in the recommendation of the Stoneville 2B and Deltapine 14 varieties (Table 8). When it is necessary to use land in which only the wilt fungus is abundant, the Miller 610 variety is preferable because it has adequate wilt resistance, high yielding capacity, and is easy to pick. Coker 100 W. R. Str. 39-5, Tifton Dixie Triumph, Delta Dixie Wilt Resistant Str. 2, Clevewilt, Cook 144-68, Dixie Triumph 25-12, Dixie 14-5 Str. 2, and Deltapine 12 are also good wilt-resistant varieties for such fields. If it is necessary to plant cotton in soil that is seriously infested with parasites causing wilt and root knot, however, only the Coker 4-in-1 variety is recommended. This variety is resistant to the combination of wilt and root knot, and produces fair yields of good-length fiber. Rhyne's Cook has much of this double resistance also, but it has a short staple length.

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